ARGOS: A SYSTEM TO MONITOR ULYSSES NUTATION AND THRUSTER FIRINGS FROM VARIATIONS OF THE SPACECRAFT RADIO SIGNAL

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Concept: Ulysses is a spin-stabilized spacecraft that experienced significant nutation after its launch in October 1990. This was due to the Sun-spacecraft-Earth geometry, and a study of the phenomenon predicted that the nutation would again be a problem during 1994-95. The difficulty of obtaining nutation estimates in realtime from the spacecraft telemetry forced the ESA/NASA Ulysses Team to explore alternative information sources.

The work performed by the ESA Operations Team provided a model for a system that uses the radio signal strength measurements to monitor the spacecraft dynamics. These measurements (referred to as AGC) are provided once per second by the tracking stations of the DSN (NASA/JPL Deep Space Network). The system was named ARGOS (Attitude Reckoning from Ground Observable Signals) after the ever-vigilant, hundred-eyed giant of Greek mythology.

The ARGOS design also included Doppler processing, because Doppler shifts indicate thruster firings commanded by the active nutation control carried out onboard the spacecraft. While there is some visibility into thruster activity from telemetry, careful processing of the high-sample-rate Doppler data provides an accurate means of detecting the presence and time of thruster firings. DSN Doppler measurements are available at a ten-per-second rate in the same tracking data block as the AGC data.

Development: In February 1994, once the need for this system was recognized, JPL started the ARGOS development effort. Changes were made in the JPL ground data system to provide tracking data over channels that had been exclusively **used** for telemetry and command data, resulting in the tracking data being available on Sun workstations in the Ulysses mission support area. At the same time, a set of programs was developed to read, process, and display the data and resulting estimates. Much of this work was done in parallel, using predefine interfaces between programs performing each of the required functions. Prototype programs were also used to investigate some of the necessary algorithms. The resulting system is capable of reliably detecting attitude dynamics in the 0.02 to 1.0 degree range with a 0.005 degree accuracy and a onc minute update rate.

The ARGOS system was first used during tests in early June 1994, and was operational for the start of continuous nutation control operations in August 1994. In addition to monitoring the nutation amplitude in realtime, the ARGOS estimates, based on historical and current data, have been used to predict the future behavior of the attitude dynamics. On a shorter time scale, the estimates from within 24 hours show the interaction between the nutation amplitude, the Earth off-pointing, and the thruster firings. During a recent period of unplanned telemetry interruption, ARGOS successfully measured the Earth aspect angle and nutation amplitude of the spacecraft when no other estimates were available.

Future: From the operational experience to date, it is clear that the ARGOS system will provide a unique view of the evolving attitude dynamics of the Ulysses spacecraft. In addition to describing the future operational experiences of ARGOS and the material discussed so far in more detail, this presentation would also include a *demonstration* of the ARGOS system **using** the offered Sun workstation facilities.